UNIVERSITY OF HOUSTON

SEMI-ANNUAL

PROGRESS REPORT

March 1 - August 31, 1966

MULTIDISCIPLINARY SPACE RELATED RESEARCH

NASA GRANT NGR-44-005-021

OFFICE OF GRANTS AND RESEARCH CONTRACTS

NASA - OSSA

September, 1966

I. SUMMARY

An appropriate portion of the total of this $150,000 three year grant has been invested in developing improved capabilities in physics, chemical engineering, mathematics and chemistry. The funds provided for electrical engineering for this period will be used at a later date when they can be more effective. These funds were used in this period to augment the program in mathematics.

During the first six months of this research development grant, the department of physics initiated theoretical and experimental research in solid-state magnetoacoustics, the diffusion of gases through metals, the microcalorimetric measurement of beta-ray energies, and the mechanism of red light emission in lunar craters. In addition, the theoretical work on hydromagnetic waves has been expanded to include solar-wind and magnetospheric plasma interactions.

The department of chemical engineering has directed its efforts toward the investigation of the fluid mechanics of flow systems in the presence of gas liquid interfaces. These studies are directed toward determining the pressure drop, the relationship of the pressure drop to the shape of the wave interface, techniques for predicting this shape and relationships involving the interaction of motion in the two adjacent planes at the interface.

The department of mathematics has directed its efforts toward investigating which nonnegative matrices are diagonally equivalent to stochastic matrices and determining the minimum permanent of the n x n double stochastic matrices. The research described for this six months period is continuing.

The department of chemistry has purchased an Optics Technology Model 130 Laser with harmonic generators, a Leeds and Northrup recorder and a dry box. A delay in shipment of the frequency doubling crystals and other ancillary equipment has limited the use of the laser to excitation of hydrocarbons. The dry box has been used for the preparation and investigation of metal complexes which are unstable in the presence of oxygen or water. The recorder has been used in gas chromatographic studies of oxidized hydrazines. The investigations initiated during the past six months are being continued.

II. DESCRIPTION OF RESEARCH EFFORTS

A. Research in Physics

1. Solid State Magnetoacoustics

The group interested in experimental studies of magnetoacoustic effects, superconductivity and solid state plasmas is in the process of establishing laboratory facilities for these studies.

A number of the experiments require that the specimens be prepared so that opposite faces are optically flat and plane parallel to high precision and that the crystals have a specified crystallographic orientation. Equipment and procedures for lapping and orientation are about 80% complete.

Magnetoacoustic and certain solid state plasma experiments require magnetic fields. For this purpose, an old magnet is being modified and it is expected to produce a 10 KG field with the required homogeneity. A 50 KG magnet was purchased with funds from other sources and is available for these studies.

A surplus x band microwave source was acquired and is being converted into a spectrometer for use in solid state plasma experiments. The magnetron on this device has enough power output so that it can also be used to excite phonons with microwave frequencies.

University funds were used to obtain a commercially available ultrasonic attenuation comparitor with frequency capabilities from 0.5 to 800 MHZ. This unit consists of a high level pulsed oscillator and tuned receiver and in addition generates a calibrated comparison signal internally for accurate measurements of changes in attenuation with some externally varied parameter such as temperature or magnetic field. Certain superconductivity and magnetoacoustic experiments are some of the many uses for this pulsed oscillator.

A low temperature station was designed and construction is 70% complete. This facility will provide controlled temperatures in the range from 1.1^{o}K to 4.2^{o}K to room temperature. In addition a high vacuum system has been assembled. This system is used to evacuate the dewar walls and to pump on the experimental "cans" in the liquid helium bath.

2. Diffusion of Gases Through Metals

In the permeation of palladium metal by hydrogen gas, hydrogen ions diffuse through the metal, recombine to form molecules, and escape as molecular hydrogen. Some experiments indicate that a small amount of hydrogen atoms are emitted. There is also evidence that these atoms

react with pure cadmium sulfide to form hydrogen sulfide gas and will cause certain phosphors to luminesce whereas molecular hydrogen does not have these properties.

To determine what factors influence the emission of hydrogen atoms from palladium experiments will be performed under controlled pressures and temperatures using a cadmium sulfide piezoelectric crystal and zinc sulfide and cadmium sulfide phosphors to detect the atoms. The crystal will show the presence of atoms by a change in frequency and the phosphors by an emission of light. Both effects can be quantitatively related to the number of atoms being emitted. The needed equipment to perform these tasks have been acquired and is presently being checked out. At the same time, the searching and acquiring of pertinent articles is being continued and the writing of the introductory part of the dissertation has begun.

3. Piezoelectric Calorimeter

Preliminary calculations concerning the measurement of average beta ray energy from two commercially available beta sources (Promethium - 147 and Sulfur - 35) have been completed. These calculations indicate that a 10-megacycle Y-cut quartz crystal oscillator can be used as a suitable temperature-measuring device for a calorimeter containing about 10 millicuries of either of these two sources. Such crystals have been obtained and frequency versus temperature data are about to be taken by use of a chromel-constantin calibrated thermocouple.

A microcalorimeter has been constructed by machining brass into a thin-walled cup-shaped vessel, the cover of which is the quartz crystal. This calorimeter has been tested with an AT-cut 10-megacycle crystal and produced no deterioration in the performance of the crystal. Both signal quality and temperature sensitivity were practically unaffected.

Because of the relatively large surface area of usable quartz crystals ($\sim$1 cm^2), a major factor limiting the sensitivity of the device is the heat loss from the crystal due to thermal radiation. Because this loss rate is proportional to the fourth power of the temperature, it is possible to overcome this difficulty by taking the measurements at liquid nitrogen temperature. Since quartz crystals have previously been used as thermometers successfully at this temperature, it appears that this poses no serious experimental problem.

Another device suitable for the measurement of small temperature changes is the thermistor, a semiconducting device whose resistance changes considerably with temperature. For example, some thermistors change resistance by as much as 4.6% per degree Centigrade change in temperature. A Wheatstone Bridge has been constructed using such a thermistor as one of the components, and a temperature differential of $0.001^{o}C$ is easily detected.

An added advantage of the thermistor is its small surface area (less than one-tenth that of the quartz crystals used). This allows a smaller microcalorimeter to be used and results in the reduction of the heat loss due to radiation as well as a larger temperature rise per unit heat absorbed by the calorimeter. Presently, the possibility of using a thermistor-microcalorimeter system as a comparison to the quartz crystal system is being investigated.

4. Interaction of Hydromagnetic Waves With Magnetospheric Plasma

The following topics are being investigated: a) ion acoustic wave phenomena in plasmas; b) the distribution of wave energy in a model magnetosphere; and c) the heating of magnetospheric plasma by propagating waves.

The first of the above topics, ion acoustic waves, is being treated by improving the current interpretations of experimental results, principally those of Alexeff and Neidegh. These experiments deal with the resonance of ion acoustic waves in a steady state discharge of fixed length oriented by an axial magnetic field. The effects of collisions, recombination, and finite wave amplitude on the dynamics of the wave are being investigated. Some improvements have been made in the interpretation of the experiments in terms of the characteristic parameters of the plasma. Methods emerge for accurately determining ion temperatures in this kind of discharge and for providing measures of recombination times for ions in the discharge. Electron temperatures can be measured accurately, provided an appropriate interpretation of the collision processes in the discharge is available. The excitation of standing ion acoustic waves and their role in scattering of higher energy electrons is also being studied. It is planned to expand the study to include experimental work on axially-confined steady-state discharges.

The second topic, the distribution of wave energy in a model magnetosphere, has been treated analytically to obtain the ray paths for relatively high frequency waves in the magnetosphere. Hamilton's wave equation and the eikonal method are used to calculate trajectories, energy flux densities, and energy densities for radiation originating at the boundary of the model magnetosphere. It is found that only a very small percentage of wave energy originating at the boundary penetrates to within $4R_E$ geocentric. The implications of this relative to heating of a mainphase ring current inside $4R_E$ by hydromagnetic radiation are that such hydromagnetic heating is quite unlikely. The screening of the inner portions of the geomagnetic field from high frequency wave energy originating near the outer boundary is tremendously enhanced by the "knee" in the plasma density near $5R_E$, which produces a large discontinuity in propagation velocities at this distance. This screening is particularly pronounced during geomagnetic disturbance. Geomagnetic and dynamical effects of wave energy will therefore be of appreciable importance on high latitude field lines for wave frequencies greater than about 0.1 hertz.

The third of the topics, wave heating of magnetospheric plasma, is being studied by examining the conductivity of the magnetospheric plasma. The real portion of the plasma conductivity is of interest in connection with dissipation of hydromagnetic or plasma waves with frequencies in the vicinity of the ion cyclotron frequency, will be significantly damped in traversing the magnetospheric plasma. Ion acoustic or hydromagnetic waves with such frequencies could be generated by instabilities at the outer boundary of the magnetosphere or by internal excitation processes related to the higher energy portion of the trapped radiation. Significant heating of the outer portion of the magnetosphere might result if the wave amplitudes are significant. Effects of internally excited ion acoustic waves on the conductivity parallel and transverse to the magnetic fields is presently being examined.

Recent satellite observations are being incorporated in our models of the magnetosphere. It is anticipated that the results of these studies will be applied to graduate degree requirements and are being prepared for publication.

5. Magnetosphere-Solar Wind Interaction

Two papers were delivered at the Annual Meeting of the American Geophysical Union, April 19 through 22, 1966. Both papers deal with geophysical effects of the magnetosphere-solar wind interaction. As indicated in the following abstracts:

Plasma instability and the polar magnetic substorm. The generation of polar magnetic substorms by inertial accelerations of the tail of the magnetosphere is discussed. Rayleigh-Taylor instability of the outer boundary of the magnetosphere and the neutral sheet inside the tail resulting from such accelerations is regarded as the source of the ionospheric currents. Mixing of the current sheaths bounding the tail with field lines connected with the auroral zone results from the inertial instabilities. This mixing leads to short-circuiting of the boundary's sheath currents to the ionosphere and the appearance of westward electrojets. Sources for the inertial accelerations are diurnal rotation of the Earth, variations in the solar wind momentum density, and possibly "wagging" of the tail by variations in the direction of the interplanetary magnetic field.

An induction mechanism for quiet-time auroras and magnetic bays. A new theory for quiet-time auroras and geomagnetic bays is derived from a study of co-rotation induction potentials in the vicinity of field lines connected to the magnetopause and the neutral sheet in the tail of the magnetosphere. Quiet-time bays are related to current sources and sinks driven by co-rotation induction potentials, and to local enhancements of conductivity in the ionosphere at the locus of field lines connecting with the magnetopause and the neutral sheet. Auroral discharge is related to adiabatic particle motion in the vicinity of this same locus. The potential of the locus is seen to differ from that of

surrounding field lines, owing to the high electrical conductivity along field lines and in the magnetopause and neutral sheet constitutes a conducting "brush" that slides over the rotating ionosphere.

Work on the proposed mechanisms for substorms, auroras, and electrojets is being continued. Emphasis is being placed on recent observational results for the magnetosphere and their connection with dynamical processes in the magnetospheric plasma. Of particular interest is the d.c. electrical conductivity in the magnetosphere as it relates to the proposed induction mechanism for auroras and bays. The morphology of induced currents and plasma motions in the magnetosphere is also being reviewed.

Dr. Kern was invited to discuss auroral and geomagnetic phenomena with the staff of the Plasmas and Fields Branch of Goddard Space Flight Center, June 16 through 17, 1966. He presented a brief talk on "Theoretical Models for Auroras and Electrojets." A related paper "The Semiannual Variation and Electrojet Models" is to be presented at the Western National Meeting of the American Geophysical Union, September 7 through 9, 1966. This paper elaborates on the instability model for the polar substorm mentioned above, accounting for the semiannual variation in the geomagnetic field in a simple fashion.

6. Red-Light on the Moon

During the summer we have begun a study to ascertain possible mechanisms for the red light reportedly observed in the crater Alphonsus on the moon[1].

Discussion of the problem with Dr. Urey revealed that he has considered the possibility that the surface of the moon might be charged, thus giving rise to a corona type gaseous discharge in gases escaping from the interior of the moon.

Our own hypothesis is that a charge can be imparted to gas escaping by flow through porous-rock and fissures by an "electrokinetic" effect. We propose that gas molecules can be ionized, or at least raised to excited states, by interaction with the solid lattice when flowing through fine pores ($\approx$ 25 Angstroms in diameter).

Two modes of investigating this possibility have been initiated. One is an experiment in which various gases can be flowed through a long specimen of porous rock at relatively high rates and the potential difference (if any) across the rock length measured. The escaping gas will also be observed visually, and with a photo-multiplier, to detect any radiation from excited molecules. This apparatus is nearly completed.

The second mode of attack is a theoretical study. We have calculated the potential energy of a molecule located at any point in a long straight

[1] Urey, H. C., Astrophysical J. Vol. 134, No. 1, July, 1961.

cylindrical pore due to the London[2] force of the solid matrix. Indications are that this should give rise to a very different equation of state for a gas in such a "pore" as compared to that for a gas in some large vessel. The possible effect of this on the behavior of the gas moving through the pore has not been evaluated as yet.

B. Research in Chemical Engineering

1. Turbulence Studies for Flow over a Simulated Oscillating Interface

The experimental facts tell us that friction in a fluid moving over a wavy liquid interface is higher than that over a smooth one. Since frictional dissipation is related to the turbulence characteristics of the flow, it seems natural to study this turbulence. However, turbulence measurements near a liquid interface are impossible to carry out due to spray formation and collision with hot wires by the moving waves. So we have built a simulated interface (see Figure 1). Here the liquid interface is replaced by a rubber diaphragm which is oscillated by connecting plates activated by a cam shaft. Now a hot wire anemometer can be used to probe turbulence behavior for a flow across this surface.

We used a constant current hot wire anemometer to study turbulent velocity fluctuations and fluctuations in turbulent shear stress. Results were subjected to spectral analysis to determine if there existed coupling between the frequency of oscillation of the interface and that detected in the gas phase by the turbulence equipment. The attached Figures 2 and 3 show some experimental results. Figure 2 clearly shows that the frequency of oscillation of the wavy interface shows up in the energy spectrum of the turbulence. While Figure 3 shows that the turbulence shear stress spectral distribution is shifted as a result of the interface oscillation.

The study has so far demonstrated several important things:

a. Interfacial oscillation is an important influence on the turbulence of the fluid passing over the interface.

b. The disturbance introduced by the interface is convected in the flow direction at the local time average velocity.

c. Disturbances introduced at the wavy wall are carried across the point of zero velocity gradient, even though local shear at that point is zero. This conclusively disproves a theory used for years to calculate pressure drop in flow systems where the wall roughness is different on different parts of the channel.

A new channel is now under construction in which simulated waves of smaller amplitude and higher wavelength can be generated. The influence of this larger structure on turbulence and on transition stability will be investigated.

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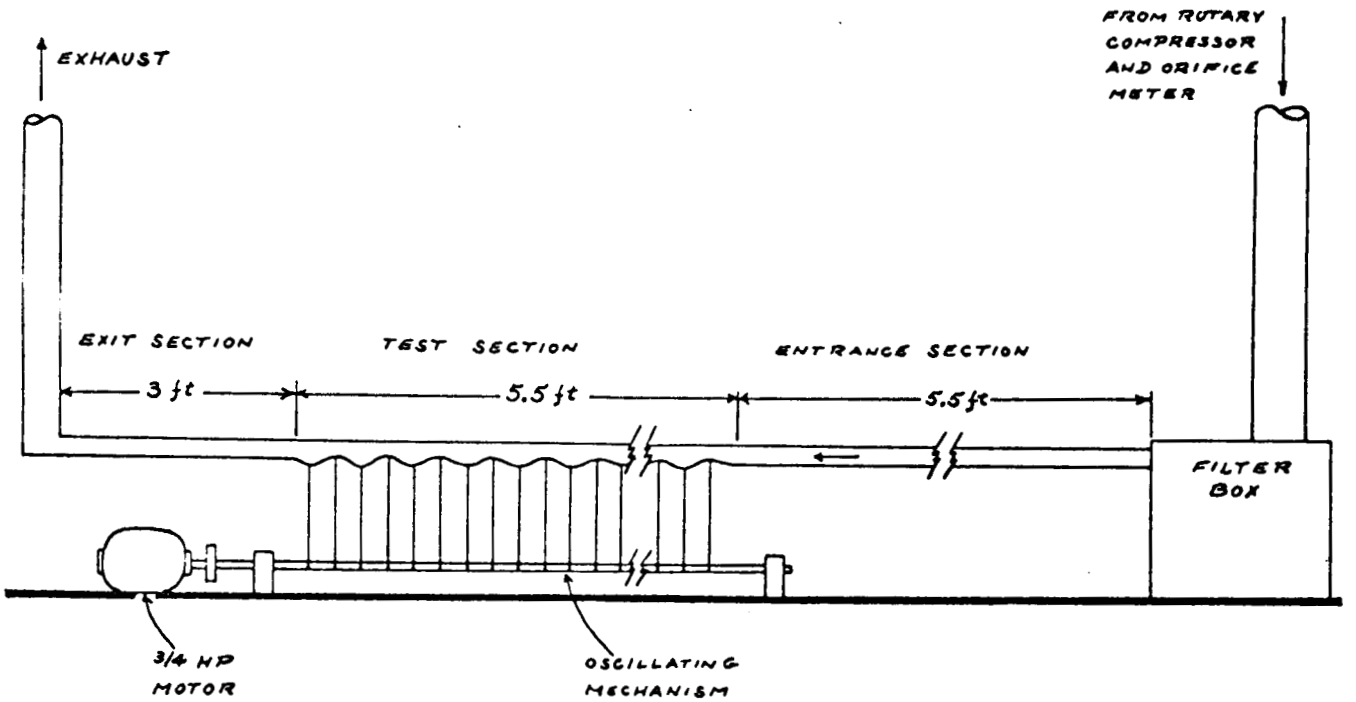
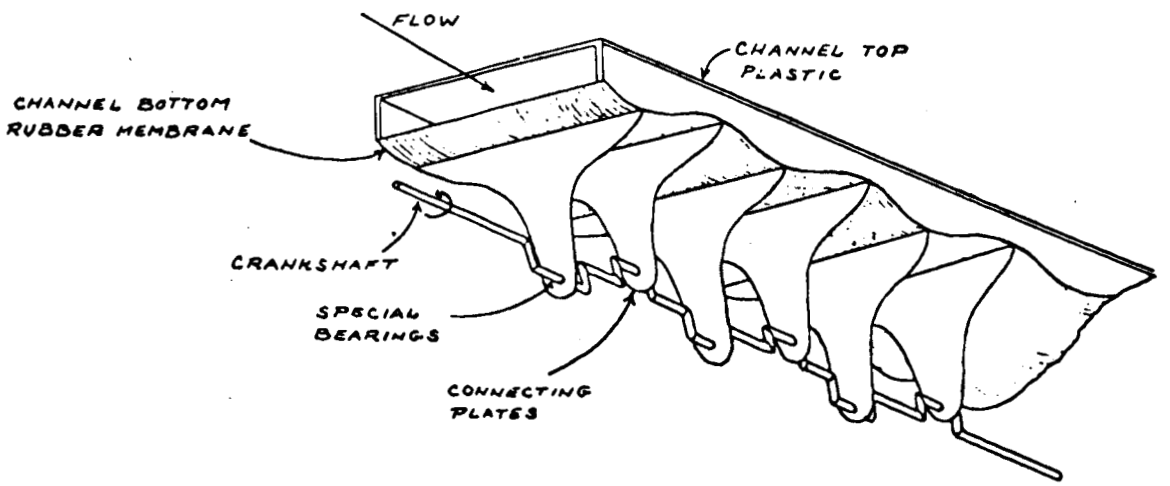
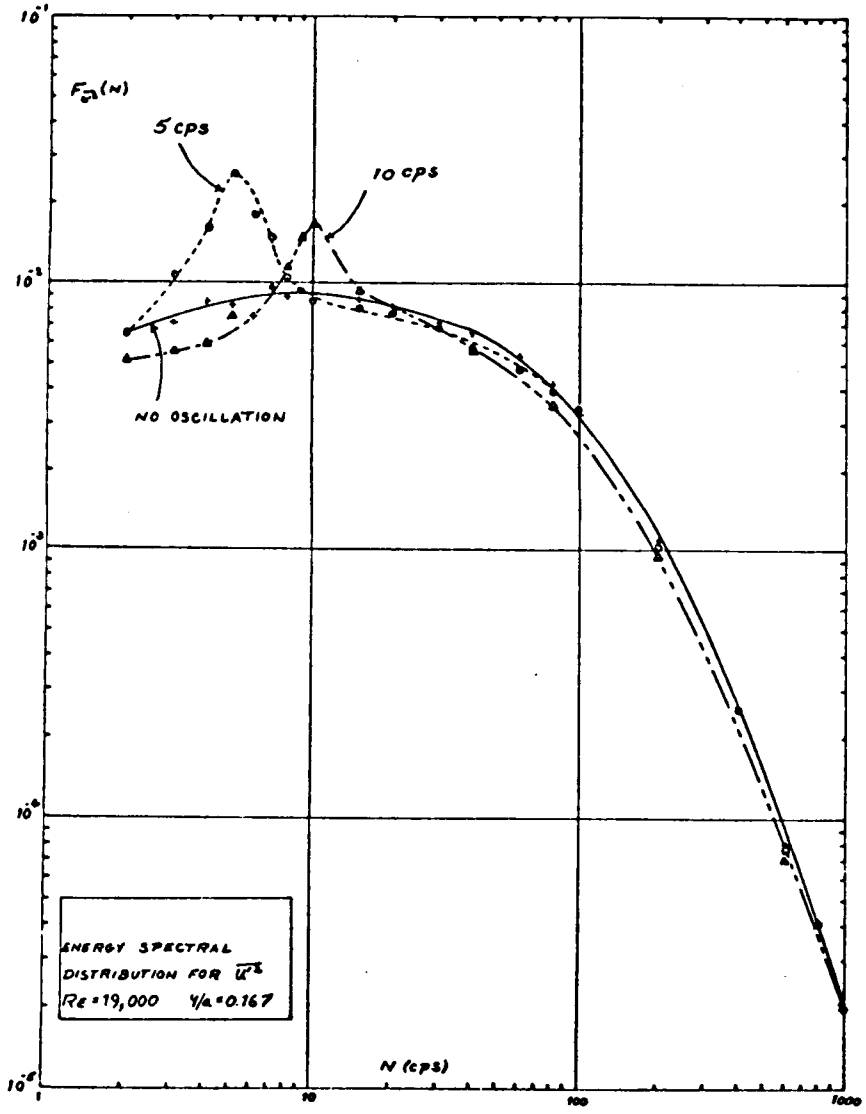
[2]See Molecular Theory of Gases and Liquids, Hirschfelder, Curtiss and Bird, Wiley Publishing Co., 1954.

FIGURE I. EXPERIMENTAL EQUIPMENT



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10 cps
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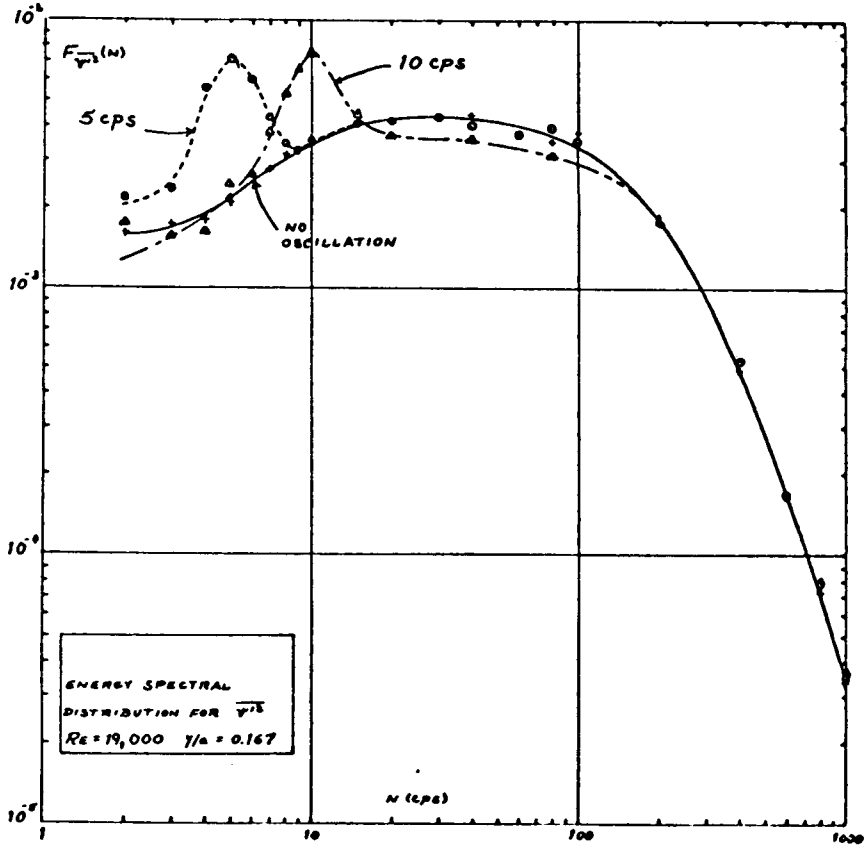
N (cps)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Re = 19,000 y/a = 0.167
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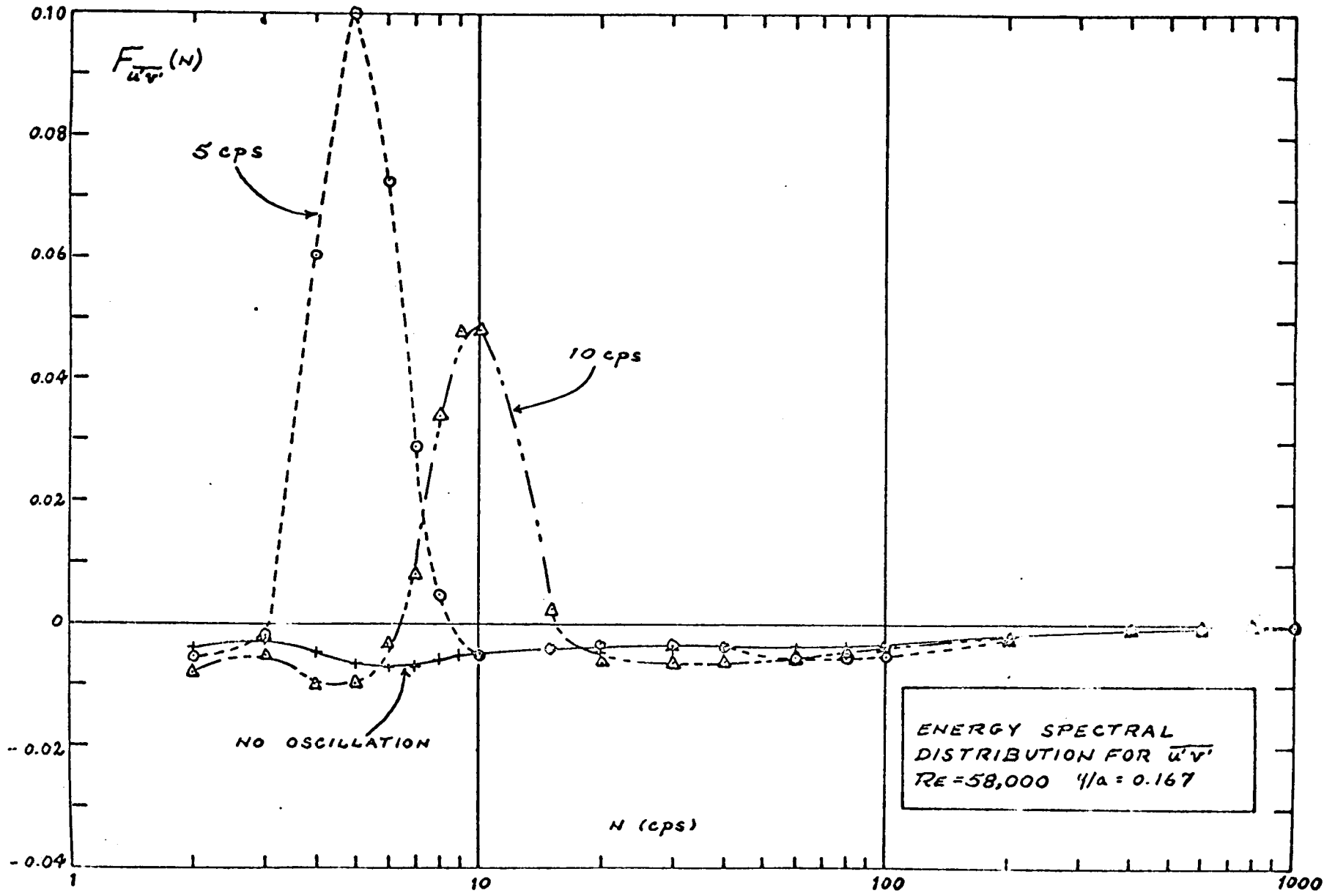
FIGURE 2


$F_{\overline{u'v'}}(N)$
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0.08
0.06
0.04
0.02
0
-0.02
-0.04
5 cps
10 cps
NO OSCILLATION
N (cps)
1
10
100
1000
ENERGY SPECTRAL
DISTRIBUTION FOR $\overline{u'v'}$
RE = 58,000 1/a = 0.167

FIGURE 3

2. Turbulence Studies for Flow over a Stationary Wavy Surface

One phase of our studies of flow over a wavy, solid surface has been completed. An actual interface consists of waves which have the profile of a wavy fixed surface which is translating in the direction of flow. The actual interface is, in an Eulerian sense, oscillating at the same time. In the studies over a simulated interface the effects of oscillation are separated. In this study the effect of shape has been studied.

Used in this work is a 13 to 1 aspect ratio channel with 2 inch spacing and 26 inches wide. On one wall there was placed a wavy surface. The flow system permitted Reynolds numbers as high as 750,000. Complete turbulence measurements were made for flow over the smooth and rough surfaces including intensity of fluctuations, spectra, turbulence scales and mean velocity distribution.

Several extremely interesting insights on the mechanics of flow over a rough surface emerged from this work:

a. The basic character of the turbulence is unchanged for flow over a rough surface from that of a smooth one. In contrast with earlier speculations, the entire effect of the protuberances is to cause local form drag.

b. The only turbulence property which changes is the macroscale measured in the direction of flue. This change is dramatic, the values over rough surfaces being of the order of ten times those of smooth surfaces. This is an important result because it explains the limiting behavior of rough surfaces in heat transfer studies.

c. The influence of the wall can be completely characterized by the use of a "wall eddy viscosity."

This work is now being continued using a constant temperature anemometer and micro probes to explore the near wall region.

3. Drop Size Distribution of Entrained Liquid

Actual interfaces flowing with interfacial shear (rocket nozzle film cooling, cryogenic flow, condensation and boiling) usually are partially unstable. As the flow proceeds, liquid drops are torn from the wave tips and are carried in the gas phase. The behavior of these drops, their trajectory, diffusional characteristics and size are important to determining pressure drop, heat transfer and, in combustion systems, their rate of reaction.

We have now developed an experimental technique which, for the first time, permits the drop size distribution to be measured. The principle of the method is simple: a drop of electrically conductive liquid

contacting two needle point electrodes in a DC circuit produces a pulse of current which can be totalized in an electronic counter. By varying the needle point spacing an average count rate curve is obtained from which the drop size distribution can be calculated. Analysis of neither pulse size nor duration is required.

Is S is designated as the needle spacing; f(D), the drop diameter distribution; D the diameter and h(s) the measured count rate; we have shown that

$$h(s) = \int_0^\infty K(s,D)\ f(D)dD$$

K(s,D) is the probability that a given drop size will strike a given needle spacing point and this can be written as an analytical expression of some complexity. For any needle spacing h(s) is measured and the problem is to extract the drop size distribution from the above integral. The rather complex electronics associated with the equipment have been successfully designed and tested over the mathematical procedures for operation on the integral evolved. Figure 4 shows the amplifier circuit, Figure 5 an example of the count rate curve, Figure 6 some typical size distributions which were counted, and Figure 7 a representation of the maximum drop size found in a series of our measurements.

Work is continuing to relate these drop sizes to the interfacial structure.

C. Research in Mathematics

The research effort has been directed toward the problem of determining which nonnegative matrices are diagonally equivalent to stochastic or doubly stochastic matrices and that of determining the minimum permanent of the n x n doubly stochastic matrices. Results of Brualdi, Parter, and Schneider ("The diagonal equivalence of a nonnegative matrix to a stochastic matrix," to appear) and of Sinkhorn and Knopp ("Concerning nonnegative matrices and doubly stochastic matrices," to appear in the Pacific Journal of Mathematics) show that corresponding to a given nonnegative square matrix A there is a unique doubly stochastic matrix of the form D_1AD_2 where D_1 and D_2 are diagonal matrices with positive main diagonals if and only if every positive element of A lies on at least one positive diagonal. Brualdi, Parter, and Schneider demonstrated existence by using fixed point theories. Sinkhorn and Knopp gave a constructive argument in terms of an iterative scheme.

These results are only a special case of a more general problem which is being investigated under this grant. Given two nonnegative n x n matrices A and B, under what conditions do there exist diagonal matrices D_1 and D_2 with positive main diagonals such that D_1AD_2 and D_2BD_1 are each stochastic? The special case $B = A^T$ is the afore mentioned

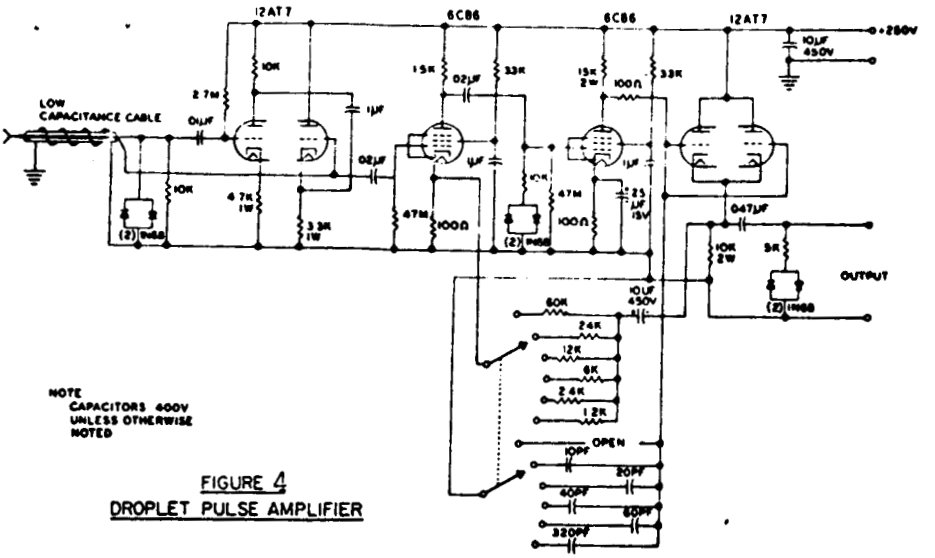
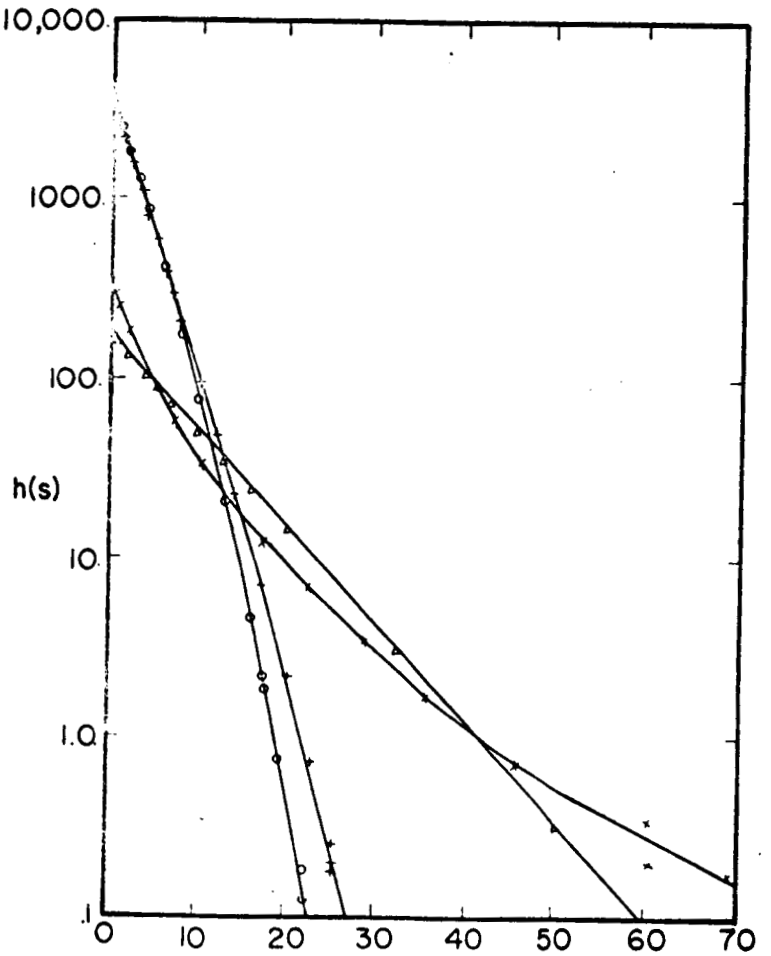


FIGURE 4
DROPLET PULSE AMPLIFIER



POINT	LIQUID RATE	GAS VEL.
△	500 LB/HR	123 FT/SEC.
○	500	273
×	2500	76.9
·	2500	253

FIGURE 5
EXAMPLES OF MEASURED COUNT RATE CURVES

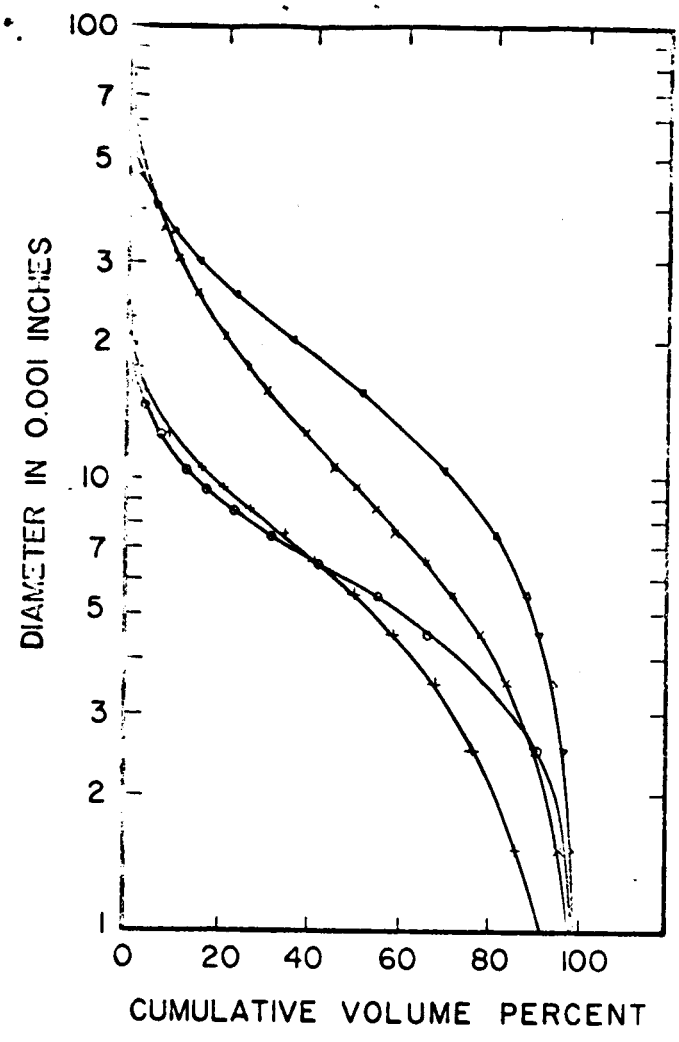


FIGURE 6
EXAMPLES OF COMPUTED DROP SIZE DISTRIBUTION CURVES:

POINT	LIQUID RATE	GAS VEL
▵	500 LB/HR	123 FT/SEC
○	500	273
×	2500	76 9
•	2500	253

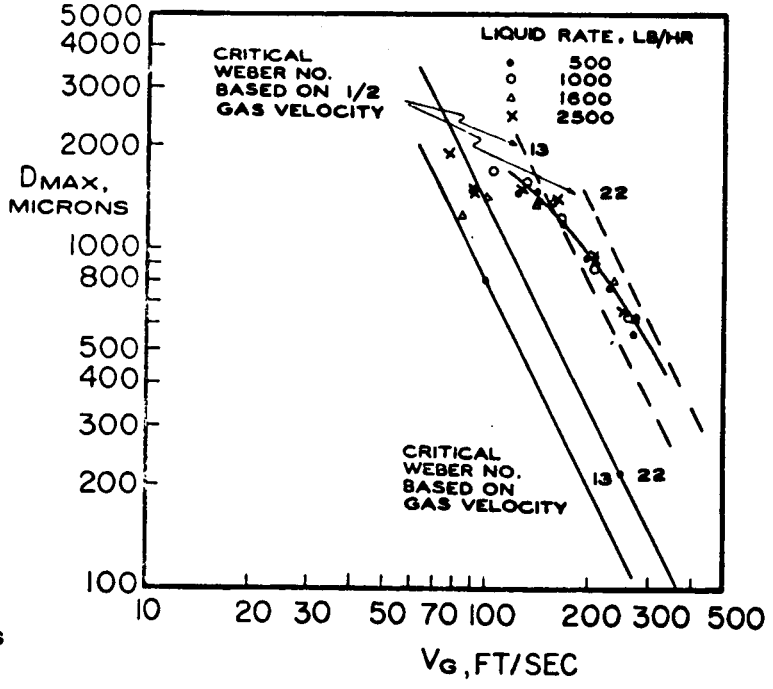


FIG. 7
MAXIMUM DROP SIZE AS A FUNCTION OF GAS VELOCITY

problem. Some partial results are known. If for every zero submatrix $B[E|F]$ in B there is a zero submatrix $A[G|E]$ in A where F and G are disjoint, then there is a unique positive number μ and diagonal matrices D_1 and D_2 with positive main diagonals such that D_1AD_2 and μD_2BD_1 are each stochastic. Of course the same result holds if the roles of A and B are interchanged.

The problem is connected with that of finding positive eigenvalues and eigenvectors for nonlinear but homogeneous monotone operators in n space. The number μ above is a eigenvalue for such an operator. An important question in this study is that of determining for which A,B pairs μ is equal to one. This is the case if B is diagonally similar to either A or A^T, but such a drastic condition is hardly necessary.

In regard to the minimum permanent question, it has been shown with the aid of the D_1AD_2 theorem that no two doubly stochastic matrices can have the same corresponding diagonal products if one of the matrices contains no 2 x 2 zero submatrix. It is conjectured that the 2 x 2 condition can be dropped. Since the permanent of a matrix is the sum of its diagonal products it would certainly be worthwhile to know if a doubly stochastic matrix is completely determined from its diagonal products.

Research will be continued toward the end of determining necessary and sufficient conditions on nonnegative matrices A and B so that D_1AD_2 and D_2BD_1 are simultaneously stochastic for appropriate diagonal D_1 and D_2 and the related minimum permanent problem. The research already completed seems promising and gives definite indication of a satisfactory completion of the problem.

D. Research in Chemistry

Three major pieces of equipment were purchased after March 1 and used for research on the Multidisciplinary Space Related Research Grant from NASA. These were an Optics Technology Model 130 Laser with harmonic generators, an L & N Recorder, and a Dry Box (Curtin Co.).

The following is a brief description of initial investigations with these instruments.

One of the major problems in the area of molecular spectroscopy is the availability of high energy, monochromatic excitation sources. Present technology in the development of lasers is such that both gas and crystal lasers are now available. The crystal lasers such as ruby can, by proper switching, deliver a monochromatic, high energy light pulse. The instrument we have purchased is capable of delivering a light pulse in the red (6943A) of a duration of approximately 5-10 nanoseconds and at a power of approximately 100 megawatts. This is capable of some modification in terms of power and pulse duration.

The particular interest is to use this unusual source to study the nature of molecular excited states including triplet-triplet absorption, potentially excited singlet-singlet absorption, and lifetimes of excited states. In addition, it should be possible to study photochemical reactions with some unique possibilities. For example, the creation of a large amount of product with a single laser burst because of the enormous photon flux. Further, because of the short pulse width, mechanisms of the reactions could be elucidated.

The principal problem with such a laser is the low energy light emitted. Most molecules require ultraviolet light for excitation. Thus, with the use of frequency doubling crystals, it is possible to reduce the primary laser wavelength by one-half with an efficiency of approximately 10%. Thus, with ruby and neodymium crystals wavelengths of 3471, 5300 and 2750A can be produced using doubling crystals.

Because of delays in arrival of the frequency doubling crystals, proper switching liquids for the neodymium rod and machined mounts for the laser head only preliminary experiments using the ruby crystal have been accomplished. The frequency doubling of the ruby wavelength and some excitations of hydrocarbons has been accomplished.

Several carboxylate ligands form complexes of Cr (II), Cu (II), Ma (II) and Rh (II) which display unique spectral and magnetic properties. These complexes form adducts with other donor molecules such as H_2O, NH_3, NO, alcohols, etc. X-ray investigations show these complexes to be dimeric species with bridging of the metal ions through four carboxylate ions. The other two ligand bonds are perpendicular to the plane of the four oxygen atoms around each metal ion. The unusual magnetic and spectral properties seem to be due to a metal-metal interaction through overlap of the half filled d orbitals resulting from the close internuclear distance of the two metal ions. The nature of the metal-metal, metal-carboxylate and metal-solvate interactions are not understood since there have been only a few studies reported on these systems. In our investigations we are studying the thermodynamic, magnetic, and spectral properties of these complexes and comparing the results to theoretical calculations carried out in our laboratory. Several of these complexes are unstable in the presence oxygen and water so the dry box obtained from the NASA grant is used in the preparation and studies on these compounds.

The L & N model H recorder has been used in conjunction with a gas chromatograph, which has been an essential tool in a current study of the oxidation of substituted hydrazines. In this study phenylhydrazine, methylhydrazine, carbethoxyhydrazine, and benzoylhydrazide have been oxidized by silver oxide, presumably to the corresponding diimide, which, after decomposition to radicals adds to carbon-carbon double and triple bonds, and substitutes on aromatic rings.

E. Report for Electrical Engineering

During the interval March 1-August 31, 1966, the Electrical Engineering Department did not expend any of the funds allotted to it under this grant.

It had been suggested early in this period that a department could delay drawing on its allottment to a later date to allow the total amount to be available over a shorter period. The Electrical Engineering Department agreed to delay using its allotted funds so that some other department could draw a greater initial amount.

The funds available during the next six months period will be used to accelerate some of the following programs in this department: Advancement of General Theory of Multiplexing Theses; Adaptive Communication Systems Theses; General Study of Satellite ELF and ULF Antennas; Step Frequency Test of Ionosphere Transmission from Satellite to Ground; Redundancy in Threshhold Logic Networks; Delta Modulation Noise Analysis; Speech Compression; Radar Detection and Signature; Propagation of E. M. Waves; Radar Systems and Assorted Signal Analysis; Volume Scattering of Radar Signal; Planetary and Earth Surface Parameters - Measurement and Analysis; Radar Clutter Studies; Electromagnetic Radiation and Antennas; Underwater Signature and Detection; Propagation of Acoustic Waves.